Nutrient Fluxes in Lake Michigan and the Impact of Episodic Events on Nutrient Cycling

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ABSTRACT

An annually recurring plume in the southern basin of Lake Michigan was examined in order to determine its effects on nutrient cycling. The plume forms in late winter-early spring and primarily consists of resuspended sediment. The dynamics of phosphorus are being studied as part of a large program examining the importance of major sediment resuspension events on the Lake Michigan ecosystem. Phosphorus is the nutrient in least relative supply and controls photosynthetic (primary) production. Other target nutrients are biogenic silica, available phosphorus, and total carbon. Samples were collected in sediment traps which intercept materials as they settle through the water column. Total phosphorus was determined using a modification of the ignition method done by Andersen (1), and analyzed on a photometric autoanalyzer. Results of the analysis showed that the total phosphorus concentrations stayed relatively constant through the time span of October 1997 through May 1998. However, the total phosphorus flux increased during the plume event off the eastern and southern shores of the lake. For example, a flux of 380 mgP/m^2/day was calculated for samples taken off the coast of Racine, Wisconsin. In comparison, fluxes in the northern parts of the southern basin ranged from 10 to 20 mgP/m^2/day. The total phosphorus flux increased steadily in these areas and other southern areas of the lake in the weeks following the plume event.

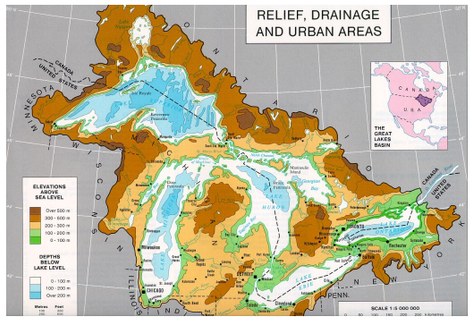

Figure 1. The Great Lakes- Superior, Michigan, Huron, Erie and Ontario - are an important part of the physical and cultural heritage of North America. Spanning more than 1,200 kilometres (750 miles) from west to east, these vast inland freshwater seas have provided water for consumption, transportation, power, recreation and a host of other uses. The lakes contain about 23,000 km^3 (5,500 cu. mi.) of water, covering a total area of 244,000 km^2 (94,000 sq. ml.) The Great Lakes are the largest system of fresh, surface water on earth, containing roughly 18 percent of the world supply. Only the polar ice caps contain more fresh water.

In spite of their large size, the Great Lakes are sensitive to the effects of a wide range of pollutants. The sources of pollution include the runoff of soils and farm chemicals from agricultural lands, the waste from cities, discharges from industrial areas and leachate from disposal sites.

Outflows from the Great Lakes are relatively small (less than 1 percent per year) in comparison with the total volume of water. Pollutants that enter the lakes - whether by direct discharge along the shores, through tributaries, from land use or from the atmosphere - are retained in the system and become more concentrated with time. Also, pollutants remain in the system because of resuspension (or mixing back into the water) of sediment and cycling through biological food chains.

Program Goal: The massive winter-spring event is providing an opportunity to explore the importance of large episodic events on whole lake ecology. Our goal is to characterize the materials resuspended into the plume, infer their sources, and assess their potential impact on the cycling and transport of nutrients and contaminants. This poster report focuses on the critical nutrient phosphorus.

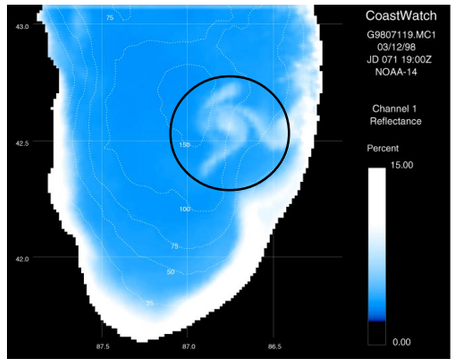

Figure 2. On March 8-10, 1998 a major storm with 30-40 knot winds and waves approaching 20 feet initiated the plume shown in the image for March 12 (which is cloud free). This event appears to be larger and more intense than any previously seen in satellite imagery. A 50 km diameter eddy appears to have become detached from the coastal region and is transporting vast quantities of resuspended materials offshore.

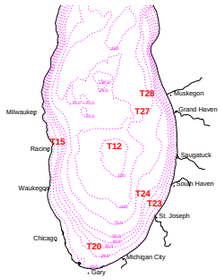

Figure 3. Locations of sediment traps. Samples of settling particulate materials were collected from October, 1997 through May, 1998 in 9 day intervals.

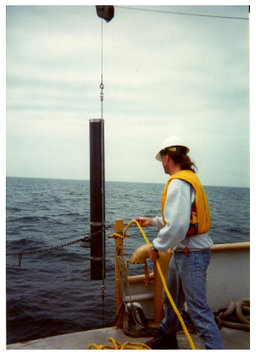

Figure 4. Sequencing trap being deployed in Lake Michigan. The trap is an 8"ID cylinder ending in a funnel with a 23 sample bottle carousel controlled by an on-board computer. Each bottle is exposed for a preprogrammed period, in this case 9 day intervals.

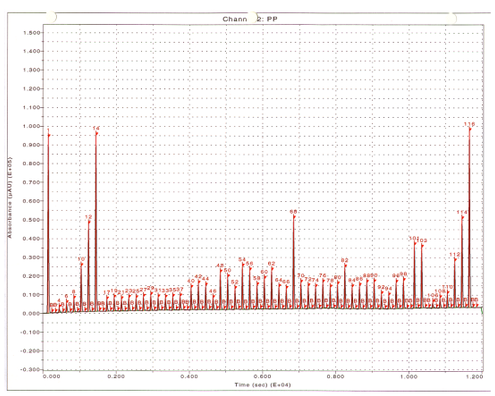

Figure 5. Summary output from the Alpchem spectrophotometric autoanalyzer illustrating the absorbance of the acid-reduced antimony-phosphomolybdate complex (see methods) measured at 880nm. Phosphorus concentrations are calculated by comparison of sample absorbance with a suite of standards.

METHODS

Methods for Total Phosphorus

- weigh out 5 - 30 mg of freeze-dried, homoginized trap material into an acid washed Pyrex test tube.
- combust sample in test tube for 2 hours at 450^{o}C
- add 10 mL of 1.0 N HCl to each sample
- place sample in boiling water bath (99 ^{o}C) for 30 minutes
- after the sample has cooled, add 30 mL of deionized, distilled water
- filter, then analyze on ALPKEM spectrophotometric autoanalyzer
- a color reagent consisting of 100 mL 5.0 N H_2SO_4, 10 mL APT, 30 mL ammonium molybdate, 60 mL ascorbic acid, and .5 mL Dowfax (surfactant) reacts with orthophosphate to form antimony-phosphomolybdate complex
- this reacts with ascorbic acid to form a blue colored complex and the absorbance is measured at 880 nm

For Available Phosphorus

- the dry sample is extracted with 0.1 N NaOH and neutralized with 1.0 N HCl
- the sample is analyzed in the same manner as above

RESULTS

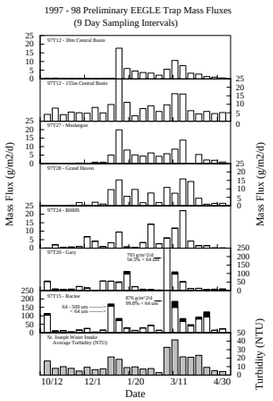

Figure 6. Mass of materials collected in the traps shown in figures 3 and 4 converted into flux units (g/m^2/day). The plume, shown in figure 2, began on March 10, clearly shown as an increase in mass fluxes close to shore and the turbidity measured at the St Joseph, MI water Treatment Plant.

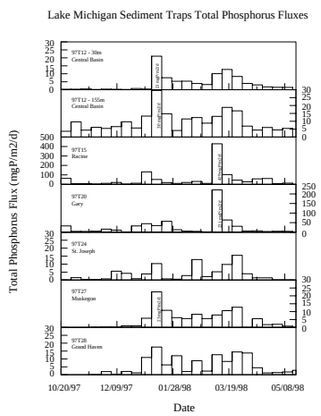

Figure 7. The trend in Total P flux closely follows the mass fluxes shown in figure 6. Two large events are clear in the nearshore traps (stations 15 and 20); the second corresponds to the event shown in figure 2. A conservative estimate of the Total P resuspended into the plume, from the trap P measurements and satellite reflectivity, is 1 x 10^6 kgP approximately equal to the measured annual load from all external sources.

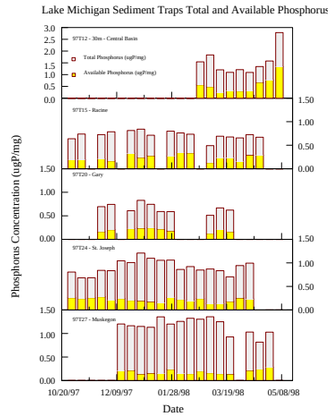

Figure 8. Concentrations of Total and Available P in the traps. The Total P remained relatively constant throughout the whole deployment period and the available (to Primary Producers) P tended to be proportional to Total P.

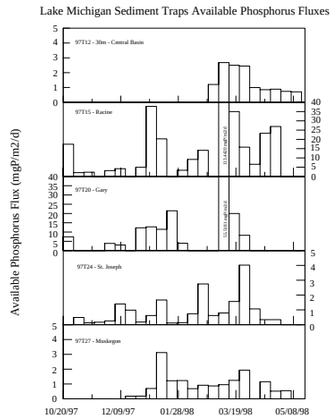

Figure 9. Available P fluxes from the sediment to the overlying water column. The large events correspond to the mass flux events. Large internal recycling events, such as that illustrated here for phosphorus, tend to buffer changes within the lake due to environmantal regulations.

SUMMARY

During its first year, the program was fortunate to have the opportunity to examine a very large plume event. To place it in context, only once before, in its 37 years of intake turbidity records, did the St. Joseph water treatment plant experience an event of similar magnitude.

Eleven sequencing traps were successfully retrieved and only one appears to have failed. Along with the extensive ship-collected samples and current meter moorings, these 230 samples provide good coverage of the event. Preliminary findings from our efforts include high particle fluxes, synchronized throughout the basin, associated with the event. The large amount of sediments resuspended by the March 10 storm reintroduced an amount of P to the overlying water column approximately equal to the combined annual load from tributaries, atmosphere, and non-point sources. A significant fraction of this material is classified as available to primary producers using a chemical extraction procedure. The timing (relative to thermal stratification of the water column), intensity, and duration of these events vary greatly from year-to-year. The importance of this internal recycling needs to be evaluated when further P regulation strategies are being considered. The results shown here, combined with those acquired in similar sampling networks over the next 2 years will be used to help calibrate P cycling models that will be used in this lake management process.

Andersen, J.M. An Ignition Method for Determination of Total Phosphorus in Lake Sediments. Water. Res. Vol 10. p 329. 1976.

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